

Technical University of Denmark



The Virtual Campus Hub Concept

Virtual Campus Hub D6.7

Badger, Merete; Prag, Sidsel-Marie Winther; Monaco, Lucio ; Fransson, Torsten ; Farinetti, Laura ; Corno, Fulvio ; Vercoulen, Frank

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Virtual Campus Hub D6.7

DTU Wind Energy E-Report

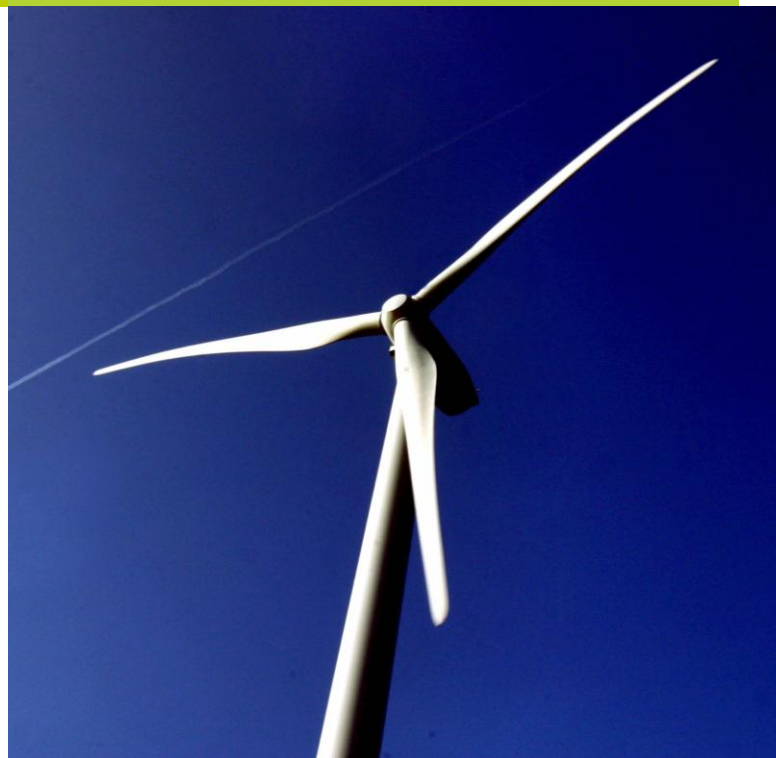
Merete Badger, Sidsel-Marie Winther Prag, Lucio Monaco,
Torsten Fransson, Laura Farinetti, Fulvio Corno, Frank
Vercoulen

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Author: Merete Badger, Sidsel-Marie Winther Prag, Lucio Monaco, Torsten Fransson, Laura Farinetti, Fulvio Corno, Frank Vercoulen
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Technical University of Denmark
Frederiksborgvej 399
4000 Roskilde
Denmark
Telephone +45 46775024
bcar@dtu.dk
www.vindenergi.dtu.dk

Contents

1	Background	5
2	The Virtual Campus Hub concept	6
2.1	Vision	6
2.2	Concept	6
2.3	Scaling up the Virtual Campus Hub concept	9
3	Functionalities – E-learning tools	10
3.1	Remote laboratories	10
3.2	Online examination tools	12
3.3	E-learning courses in wind energy	13
3.4	Best practises for the design and use of E-learning tools	15
4	Functionalities - E-link functionalities	18
4.1	StartApp	18
4.2	Best practises for the design and use of E-link functionalities	19
5	Functionalities – collaboration environment	21
5.1	MS SharePoint and the Virtual Campus Hub team site	21
5.2	Unified communications tool	21
5.3	Best practises for the design and use of collaboration environments	22
6	Infrastructure	24
6.1	Architecture of the Virtual Campus Hub infrastructure	24
6.2	Connections achieved in Virtual Campus Hub	26
6.3	Points of attention for using Géant/eduGAIN	27
6.4	Where should we go from here?	29
7	Presentation in portal	30
8	Impact	32
9	Business models in Virtual Campus Hub	34
10	Other initiatives supporting the vision of Virtual Campus Hub	35
10.1	Related projects	35
10.2	Massive Open Online Courses (MOOC)	36
10.3	Gamification	36
11	Conclusions and outlook	38
11.1	Achievements in Virtual Campus Hub	38
11.2	Outlook for the future	38
	Acknowledgements	40
	References	41
	Appendix: Deliverables of project Virtual Campus Hub	42

Preface

The research infrastructure project Virtual Campus Hub (VCH) runs from October 1, 2011 to September 30, 2013. Four technical universities in Europe, who are all active in the field of sustainable energy, form the project consortium: the Technical University of Denmark, The Royal Institute of Technology in Sweden, Politecnico di Torino in Italy, and Eindhoven University of Technology in the Netherlands. The project is partially funded by the European Commission under the 7th Framework Programme (project no. RI-283746).

This report describes the final concept of Virtual Campus Hub. It gives an overview of the project achievements and recommends best practices for the use of the Virtual Campus Hub elements: a series of applications for online teaching and collaboration which are connected to a technical platform, the Virtual Campus Hub portal, using the European research infrastructure Géant/eduGAIN.

1 Background

Virtual Campus Hub is a 2-year project (2011-13) supported by the FP7 programme of the European Commission (E-infrastructures). Partners in the project are four technical universities in Europe who all have a strong expertise in sustainable energy:

- The Technical University of Denmark (DTU) - coordinator
- The Royal Institute of Technology, Sweden (KTH)
- Politecnico di Torino, Italy (Polito)
- Eindhoven University of Technology, Netherlands (TU/e)

Initially, the concept of Virtual Campus Hub has been defined as follows (from Annex I of the project “Description of Work”):

The Virtual Campus Hub project will develop and implement the tools and e-learning platforms needed to establish a European and potential world-wide Virtual Campus network primarily for technical universities and business schools.

The Virtual Campus network will use the European e-infrastructure network incl. Géant as the communication backbone. The project will formulate end-user demands for high-quality services in support of a global virtual campus network based on a Virtual Campus Hub concept.

The Virtual Campus Hub will be developed through pilot use of the hub elements with special emphasis on the integration of research, innovation and education in sustainable energy. The Virtual Campus Hub consists of the following components:

- 1. A technical platform that can deliver virtual meeting spaces for lectures, conferences, laboratory and numerical exercises, as well as innovation tools, executive learning modules, self-study, etc.*
- 2. A set of documented best practices for the use of the platform for courses, teaching & learning methods, innovation processes, networking and joint programs, developed through continued complementary on-site activities.*
- 3. A growing inventory of staff competence and experience gained from using the Virtual Campus Hub for enhancing quality and scaling-up innovation, education and training activities primarily related to sustainable energy, combined with dissemination and communication of the resulting best practices*

The VC Hub project builds on activities and ideas concerning e-learning and virtual campuses that are currently being pursued by several universities and research organizations in Europe and combines the emerging e-infrastructure potential for high quality virtual communication with many types of audiences.

2 The Virtual Campus Hub concept

2.1 Vision

Universities have an increasing number of and increasingly diverse relations with the outside world but Information and Communications Technology (ICT) is still inward looking. Individual institutions have plenty of tools available, but using them across an institution's border is cumbersome. Labour-intensive workarounds offer far from perfect solutions. Virtual Campus Hub aims to support a number of activities that are common today for international cooperation in the field of education, research and innovation:

- *Collaboration between universities, incl. research institutes:* Joint programs in education, research collaborations.
- *Collaboration between universities, research institutes and businesses:* Involvement of external experts in education programs, graduation, PhD, post doc projects and other research collaborations, support of start-up initiatives.
- *Collaboration within networks of universities, research institutes and businesses:* Increasingly, collaboration on education, research and innovation takes place in larger networks focusing on strategic areas such as energy, ICT and health.

The driving vision of Virtual Campus Hub is to work towards a better use of shared resources in connection with sustainable energy education, research, and innovation. Sharing of resources provides a basis for further advances in the field and for unlocking a vast amount of new scientific knowledge to the European, and potentially the global, learning community.

The vision of Virtual Campus Hub is well aligned with the [European Strategic Energy Technology Plan](#) (SET-plan) goals and roadmaps. These call for an increase of the European RD&D effort in energy. To achieve this, a boost and integration of education, research, and innovation is needed. Up-scaling of education and training is necessary to meet a foreseen shortage of skilled employees in the European energy sector.

2.2 Concept

A virtual campus hub is a collection of functionalities and infrastructure services that enable seamless collaboration within *virtual organizations*, i.e. two or more organizations that are formal or informal partners and cross the borders of institutions, countries, or communities (e.g. university-industry). The objective of the Virtual Campus Hub project has been to formulate a concept for such a virtual campus hub and to setup a pilot environment that can demonstrate how a virtual campus hub could work in practice.

The concept proposed in this project is quite broad, as the concept deals with a “complete” virtual campus hub for a cross-institutional and cross-border setting. The approach is to develop a number of functionalities and use these in a cross-institutional and cross-border setting through the infrastructure that is being put in place by Géant and the National Research and Education Networks (NRENs) i.e. using NREN federations and eduGAIN. Users are able to access the functionalities with their home institution’s account and the management of users and groups is handled centrally. A portal is used as the access point for the Virtual Campus Hub functionalities. Project Virtual Campus Hub represents a pioneer effort when it comes to establishing such connections at the international level.

The Virtual Campus Hub consists of three different components (Figure 1): functionalities, infrastructure, and a portal.

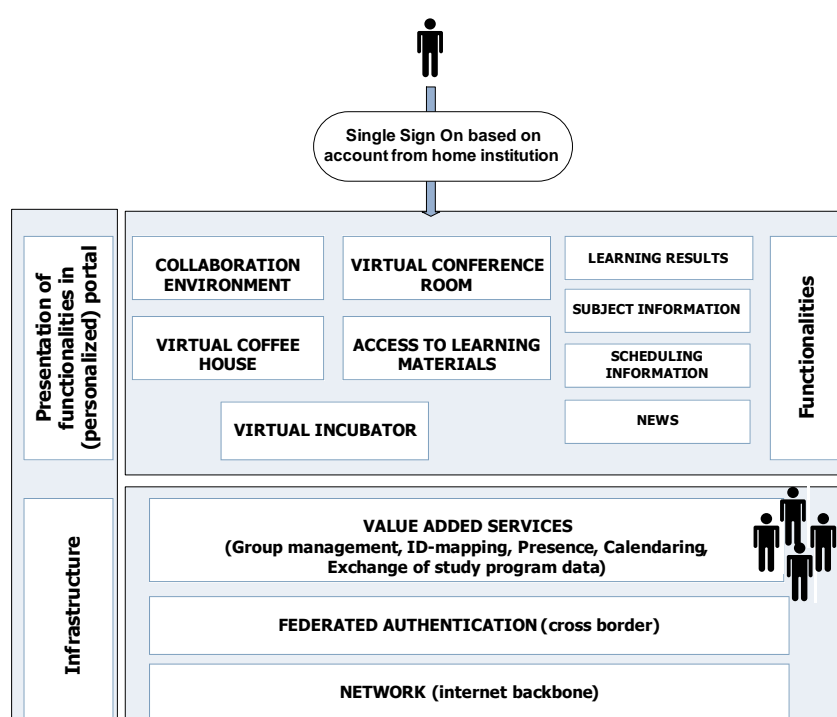


Figure 1. Overview of the Virtual Campus Hub concept: functionalities, infrastructure, and presentation through a personalised portal.

Functionalities

The functionalities are the end user applications used by students, teachers, researchers, administrative staff, company members and other external participants involved in the collaborative activities of the Virtual Campus Hub consortium. The functionalities can be grouped in a small number of categories; representing the types of activities they support (e.g. learning materials, collaboration tools, virtual incubator functionalities, exchange of study program data).

As outlined in Figure 2, each of the partner universities in Virtual Campus Hub has numerous in-house applications. A series of additional applications have been developed as part of the project. The new applications are used to demonstrate the inter-connection of universities and services via the European E-infrastructure Géant/eduGAIN. Additional functionalities are available from previous projects (the virtual conference room and coffee room) or are developed only conceptually in project Virtual Campus Hub (e.g. exchange of study program data).

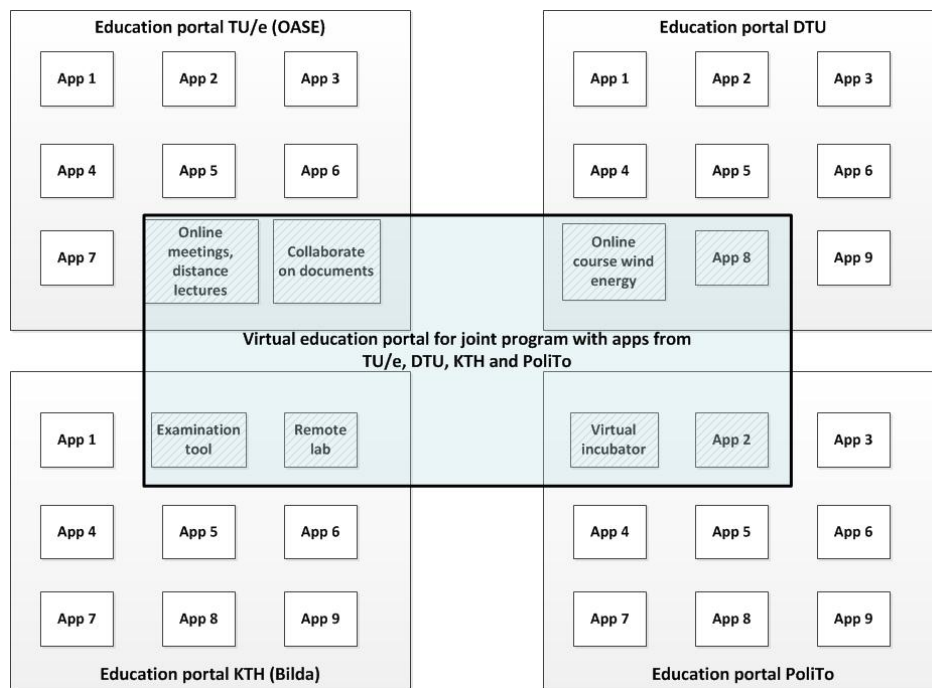


Figure 2. Outline of the functionalities of Virtual Campus Hub concept, which are inter-connected across national borders using European research infrastructure.

A very important aspect of the Virtual Campus Hub concept is that partners should, in principle, be able to connect any service they wish to the Virtual Campus Hub environment without having to conform to a common standard; they only need to conform to the general standards for connecting the services to the VCH. The services might be in-house services or they might be offered by third parties. They can be existing or new and hosted by an institution or in the cloud.

Infrastructure

The integration of functionalities in the Virtual Campus Hub environment relies on an infrastructure backbone connecting the partners to their national federation and the national federations to each other via eduGAIN. The Virtual Campus Hub partners act both as identity providers (IdPs) and service providers (SPs) in most cases. For a couple of the Virtual Campus Hub functionalities, third parties are involved as SPs (cloud service providers).

Some of the connections mentioned above were already in place from the start of the project and others have been established during the course of the project. A few connections could not be achieved within the timeframe of project Virtual Campus

Hub. Ideally, the connection of new elements to the Virtual Campus Hub should be as easy as typing an URL. However, this project has shown that there are still many barriers to break down before this goal can be achieved at the international scale.

Presentation in a portal

The functionalities of Virtual Campus Hub are presented in a demo portal at TU/e. The purpose of the portal is to show that it is possible to present and access functionalities from different institutions in a coherent and flexible way and potentially to reuse them in other portals supporting the same standards.

A major advantage of the Virtual Campus Hub concept is that users (IDs) are managed de-centrally by the institutions themselves (as IdPs) and that their group memberships can be managed centrally. This means one can reuse group definitions to manage access to several applications at the same time. This lowers the administrative burden for the collaboration initiative considerably, especially when it scales up. Once the infrastructure has been put into place, it is relatively easy to define which learning content any given group of students (e.g. students from different universities who follow a joint educational program in energy) should have access to.

2.3 Scaling up the Virtual Campus Hub concept

The Virtual Campus Hub concept has been designed with up-scaling and re-usability in mind. The technology and the lessons learned through project Virtual Campus Hub have been documented in a series of reports (see section 0 for a list of deliverables), which can be used by others who wish to establish a similar framework for education and collaboration online. More specifically, the following types of collaboration would potentially benefit from the Virtual Campus Hub concept in the future:

- Initiatives for (strategic) partnerships in research or education (joint programs)
- The EIT KICs that a university is involved in
- Ad hoc collaborations in research or education
- Partnerships with businesses in the field of research or education
- Libraries, e.g. to open up data sets to partners in research or to combine different data sets (cf. the [Dataverse](#) initiative).

In the following, the main achievements of project Virtual Campus Hub are described for each of the three components in the concept (functionalities, infrastructure, and portal). Based on the experiences gained in the project, recommendations of best practices for using the Virtual Campus Hub applications are given and some important points to consider when re-using the technology are listed.

3 Functionalities – E-learning tools

The term ‘E-learning’ indicates that digital technologies are used to develop new educational practices as well as enhancing traditional educational practices. The term can denote both the digital tools and technologies used in the student’s learning process and the new practices of the teachers and students that are brought about from using these tools.

In 2011, when Virtual Campus Hub was kicked off, the most widespread type of E-learning was through streaming of live or recorded lectures from universities and other educational institutions. E-learning was typically characterised by one-way communication, perhaps supported by traditional classroom teaching where a dialogue between teachers and students could evolve.

Web 2.0 technologies have offered a range of new possibilities for communication online and facilitated two-way communication through forums, wikis, and blogs – altogether known as social media. As the use of social media has grown and developed, integration with web sites and learning platforms has also taken place. Today most learning managements systems support group discussions in a synchronous or asynchronous manner as well as online meetings with audio and video. The E-learning applications developed in Virtual Campus Hub are amongst the first to take full advantage of these new possibilities.

Three types of E-learning applications have been developed in Virtual Campus Hub: remote laboratories, online examination tools, and online courses in wind energy. The applications have been tested in connection with real teaching situations both internally at the partners of Virtual Campus Hub and externally with participants from other partners or from the sustainable energy community in general.

3.1 Remote laboratories

The remote laboratories developed at KTH include a remote cascade lab, a pressure measurement lab, and a flutter lab for use in connection with courses in Turbomachinery. The following aspects have been prioritised in the design of remote labs:

- *Reusability* through modular design
- *Accessibility* from any device (PC, tablet, smartphone) with no software installation
- *Pedagogical value* through self-assessments, evaluation forms, interactive tools, and online collaboration

Through the remote labs, students *anywhere* can get access to real laboratory equipment for distant-based experiments in Turbomachinery. An online booking

system is used to manage the participants' access. The advanced laboratory equipment is controlled remotely by the users and video is used to view the lab facilities. A graphical user interface displays the lab settings and outputs. The remote labs are described in further detail in the reports [D2.2 Implementation of E-learning tools](#), [D2.3 Report on pedagogical improvement](#), and [D3.2 Trial implementation and test of two E-learning tools](#) and have a dedicated [web site](#) at KTH (Figure 3).

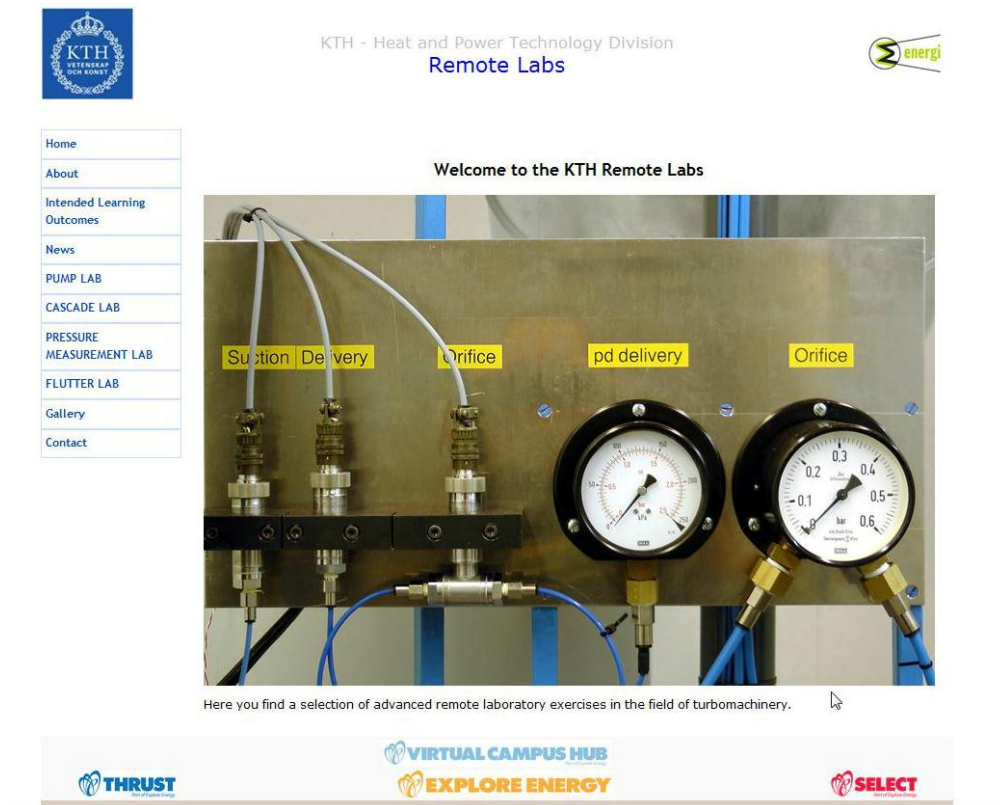


Figure 3. The start page of the [web site](#) about Remote Labs at KTH.

Main outcomes

The main outcome of the remote lab development and testing in Virtual Campus Hub has been to take a step ahead in *accessibility* of remote labs – now from any device with no software installation. Further, the work of Virtual Campus Hub has proven a successful integration of remote labs in on-going courses and guidelines have been produced for better achievement of target skills of remote labs. Virtual Campus Hub has also proven the applicability of remote labs as independent learning modules.

The testing performed in Virtual Campus Hub has helped to build up an increasingly positive attitude of institutions, teachers and students towards the adoption of remote labs as shared services in academic curricula – also across national and institutional borders. Companies have shown an interest in providing remote labs and other research institutions have expressed their interest in developing and using this type of E-learning application.

Remaining challenges

Remaining challenges in connection with remote labs are mostly related to the integration of services such as booking of physical resources, authentication, authorization, online learning material, and examination into a single learning platform. Another challenge is to get institutions even more interested and involved in the sharing of remote laboratory facilities.

3.2 Online examination tools

A series of online examination tools have been developed at KTH to push for a switch from paper-based examinations into computer-based examinations with automatic correction. This could potentially free some of the teacher's time for other activities and thus enhance the quality of learning.

Online tests have been used at KTH for several years but teachers have been doubtful of their quality and students have found them confusing and not reflecting their real knowledge. The new developments in Virtual Campus Hub have focused on implementation of new pedagogical concepts combined with the last technological advances of LMS for the improvement of online exam tools.

Two types of tests have been developed in the project:

- Multiple choice questions (MCQs) based on a large pool of questions with tens of possible correct and incorrect alternatives.
- Calculation exercises with "Twin-tracking Method": a parallel calculation process checks the student's answer for the correct procedure and equation, regardless of its deviation from the correct value. In this way, partial grading to correct procedures can be given.

Main outcomes

The examinations tools have been used in connection with nine different energy courses at KTH (Table 1). Students were positive towards the use of LMS and online learning tools and of self-assessments in particular and saw the benefits of the twin-tracking method and the programmed MCQs. From the teacher's perspective, the online examination tools were viewed as convenient and effective when a large number of students compensates for the programming time.

Remaining challenges

The online examination tools of Virtual Campus Hub have not yet been compared directly with corresponding paper-based exams. A direct comparison between the virtual and physical processes is expected to add further confidence in switching from paper-based to online exams both from the teacher's and student's side. In line with the Virtual Campus Hub objectives, teachers should be motivated further to share MCQ databases such that resources are freed from duplicate efforts and perhaps used for interactive activities instead.

Table 1. Overview of the use of online examination tools in courses at KTH.

Courses at KTH	MCQs			Calculation Type			Year	Students active in the course
	Exercises	Assignments	Exam	Exercises	Assignments	Exam		
Sustainable Power Generation			✓			✓	2012	~ 120
Combustion Theory		✓	✓		✓	✓	2012	25
Applied Heat and Power Technology		✓	✓		✓	✓	2012	90
Renewable Energy Technology		✓	✓		✓	✓	2012	~230
Turbomachinery	✓	✓	✓		✓	✓	2012	125
Thermal Turbomachinery	✓	✓	✓			✓	2013	48
Jet Propulsion Engines	✓	✓	✓		✓	✓	2012	33
Airbreathing Propulsion II	✓	✓	✓			✓	2013	8
Rocket propulsion	✓	✓	✓	✓	✓	✓	2013	22

A major barrier for the wider use of online examination tools is the fact that it is almost impossible to check a student's ID online. Today, students are mostly gathered physically to take an exam; even if the exam is online. This is feasible as long as students of a programme or course belong to the same university. New solutions have to be invented in support of a 'global university' vision where students can follow programmes or courses from anywhere in the world and combine their own virtual degree.

3.3 E-learning courses in wind energy

DTU has developed a wind energy course called 'WAsP E-learning'. The course is targeted at employees in the wind energy industry and complements an existing physical course in the Wind Atlas Analysis and Application Program (WAsP). Both courses are offered to the industry on commercial terms and any income generated by the courses is used for further development of WAsP.

The WAsP E-learning course is designed for a structured and modular learning process. The course has nine course modules and each module follows a fixed structure with the use of many different learning elements (i.e. recorded presentations, hands-on exercises, self-tests, group discussions and assignments). The course facilitates a flexible learning style where participants and teachers can work any time they like but follow the same course module every week. The course is run from the LMS 'itslearning'; a cloud service which is provided by an external provider.

The WASP course design is inspired by a five-stage pedagogical model (Salmon, 2011) where emphasis is put on building up a community feeling amongst course participants early in the course. Through simple socialising exercises, the participants are trained to communicate and share knowledge online. The help and support from fellow course participants and the teachers is a motivating factor when it comes to working on the course and fitting it into a busy working day routine.

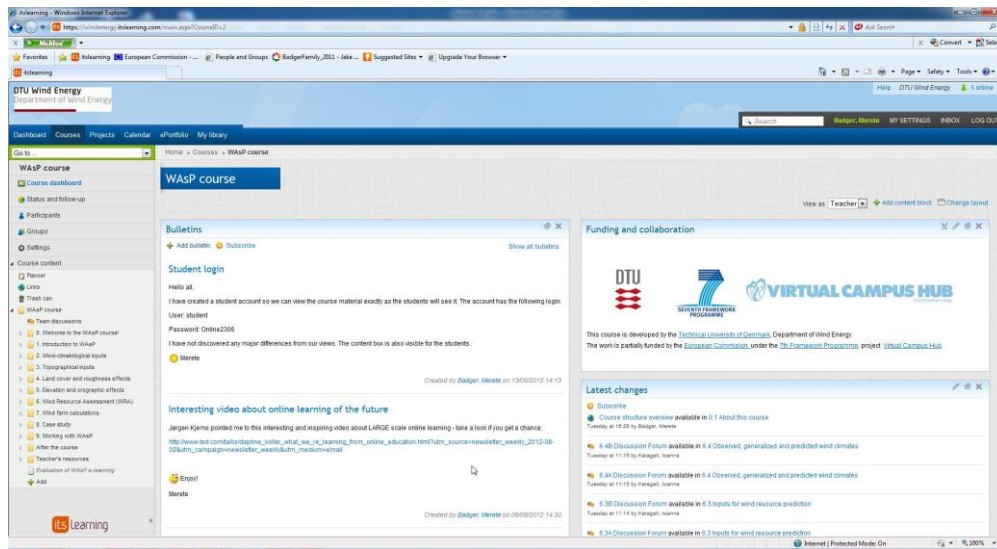


Figure 4. User interface of the E-learning platform 'itslearning'.

More information about the wind energy course is available in [D3.2 Trial implementation and test of two E-learning tools](#) and in Badger *et al.* (2013). Figure 4 shows the interface of the learning platform 'itslearning', which is used for the course.

Main outcomes

Two test runs of the WASP course have proven that a completion rate close to 100% of the participants can be achieved through this type of interactive and flexible E-learning course. Another important outcome of the course development and testing is that participants seem to learn more during a 9-week E-learning course as opposed to a compressed 3-day physical course because the online course offers an opportunity to finish up the exercises in WASP and to reflect over and discuss the theory as well as the practical WASP work. A self-test is under development to test this hypothesis further on both E-learning and physical participants in future WASP courses.

The testing in Virtual Campus Hub has been a unique opportunity to experiment with the course content and to improve the quality according to participants' feedback. One of the most important learning points from the tests are that the quality of learning content as well as audio and visual presentations has to be higher for an online course than for a physical course where the teacher's personality can somewhat compensate for imperfections in the learning material.

The recruitment process for course participants – both for the test courses that were offered at no cost and for the first commercial course run – has indicated that there is an interest in the wind energy industry for learning online. E-learning courses have several advantages over physical courses in the context of wind energy. The sector is expanding rapidly around the globe and particularly in Asia, North America, and South America. Course participants from these areas can reduce the cost, the time, and the carbon footprint of taking a course significantly by choosing an online course instead of traveling to DTU in Denmark.

The course development in Virtual Campus Hub has inspired others at DTU's Department of Wind Energy to develop online courses for continuous education. Two new courses are in preparation at present, which follow the same pedagogical and technical format as the WAsP course.

Remaining challenges

One of the main challenges that remain in connection with online courses is to facilitate online exams. Unless course participants are gathered physically to take a final exam, it is impossible to check the identity of course participants. E-learning courses thus rarely release any ECTS points but only certificates. This barrier is the main reason why the integration of E-learning courses in university programs and courses has been somewhat slow. In connection with Virtual Campus Hub and other related projects, a continuous dialogue with the university administrations at the partners has taken place in order to integrate E-learning further into traditional university teaching for example via the 'flipped classroom' approach where lectures are given online and the teachers and student can spend their time together in more interactive ways.

3.4 Best practises for the design and use of E-learning tools

The E-learning tools developed in Virtual Campus Hub have been tested in real teaching situations through a series of virtual events. These are described in the deliverable [D3.4 E-learning programmes and courses evaluation report](#). Based on the feedback collected from students, teachers, and E-learning consultants, the project team recommends the following best practises for the design and use of E-learning tools:

Remote labs

Design:

- To ensure scalability, the laboratory exercise should be designed as an independent learning module, with specific prerequisites and specific intended learning outcomes.
- The way the laboratory exercise is structured and the corresponding knowledge material should give enough information to compensate for the absence of a physical instructor while ensuring some independent initiative. Recommended is the integration of self-study questions after assigned tasks and the introduction of optional tasks.

Use:

- Lab teams of 3-6 persons are recommended in order to promote peer-learning and development of social skills while ensuring that all members have an active role in the remote experimentation.
- The use of interactive tools for content sharing, group discussion, live chat or video available to all team members (preferably the Virtual Campus Hub SharePoint environment) is to be promoted.
- The same remote laboratory can be integrated in different courses and addressed to different classes of users (students, researchers, professionals) by selection of the proposed intended learning outcomes and corresponding knowledge material.
- Integration of a remote laboratory during lectures might be beneficial to highlight and discuss practical aspects, while it is to be avoided in an exam as it might lead to stress and confusion.

Online examination tools

Design:

- Advanced functionalities should be utilised for building complex multiple choice tests (e.g. random ordering, selection from a large pool of questions, variable number of correct and incorrect questions).
- Advanced functionalities should be utilised for building calculation exercises that take the process, and not just the correct answer, into account (twin-tracking)
- Open-ended questions, which are common in paper-based exams, should be replaced with complex multiple-choice questions.

Use:

- Online examination tools should be used frequently throughout a course e.g. for self-tests in support of achieving the student's learning objectives
- Considerations about ID check of students should be made before an online exam is prepared.
-

E-learning courses in wind energy

Design:

- Online courses are best developed as a team effort. A team size of 3-5 persons is ideal to facilitate a creative and yet efficient process. A larger team size might lead to more inconsistency in the course material, which has to be corrected

later.

- Online courses should be designed as learning modules, which can be used independently in many contexts (e.g. for blended learning).
- It is essential to define learning objectives for each course module and to facilitate that students follow-up on their own learning e.g. through development of self-assessments, quizzes, and control tests in addition to the mid-term and final exams.

Use:

- In the execution phase it is an advantage to have a group of teachers who are capable of running a given online course. This gives more flexibility and makes up-scaling easy in case the demand for a course increases.
- Online courses should be as interactive as possible through the frequent use of group discussions, live chat, or video conferences. It is important to also train the teachers to use these means of communication.
- Special emphasis should be put into building up a learning community where students communicate frequently and benefit from each other's help and support.
- Follow-up on student's progress is essential for achieving a high completion rate for an online course.

4 Functionalities - E-link functionalities

E-link functionalities are tools that aid the involvement and information exchange with innovative small and medium size companies (SMEs) and entrepreneurs.

4.1 StartApp

StartApp is an interactive tool developed by Polito for support of start-up businesses. The application facilitates the initial steps of developing a business plan for a new idea (the pre-incubation phase) and seeks to establish a new link between education and innovation.

Main characteristics of the designed service include:

- The target users are post-graduate persons, who aim at building new and innovative companies in the Energy Sector.
- The service will follow such users in their pre-incubation phase. In this phase, there is a mix of learning activities (about business models, economics, but also technology, market structure, etc.) with some initial research and business development. Polito has analysed, with the help and the input from local incubators, and proposed which on-line functions are best suited to this phase of the innovation/incubation process.
- Functionalities and implementation were designed in collaboration with other Virtual Campus Hub partners, but also with the I3P Incubator in Torino, Italy.
- Users of the website must be recognized as part of “Innovation Teams” (at this stage, the companies are not formally registered, yet). Each innovation team may be followed by a “Tutor” from a recognized Incubator.

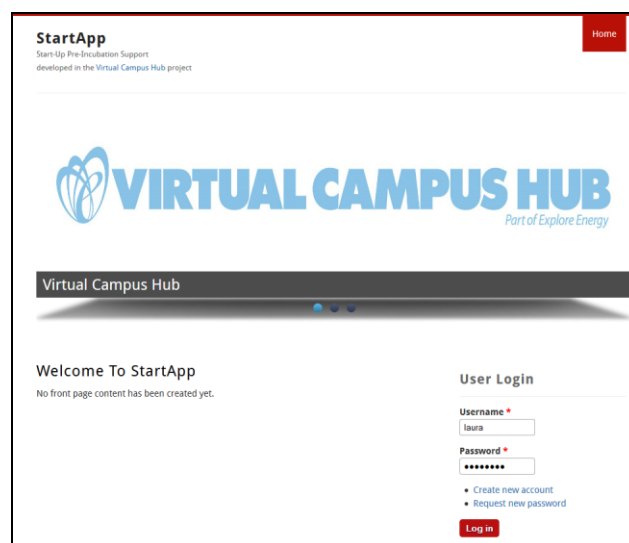


Figure 5. The access page for StartApp; an online tool for initiating a business plan.

StartApp can be accessed at <http://toce.polito.it/vchub/> (username: demouser, password: demouser). Personal accounts are setup upon request). Figure 5 shows the access page for StartApp.

StartApp includes the following functionalities:

- Smart list of web links (related to energy)
- Patent database access
- Market and industry databases
- Forums and other social networks tools
- Osterwalder canvas builder

The E-link functionalities are further described in the reports [D3.3 Trial implementation of two examples of incubator processes](#), [D4.2 E-link functionality integrated into the VC Hub](#), and D4.3 E-link evaluation report. Using this virtual application for pre-incubation, individuals who have got a new idea can quickly go through a screening process to find out whether the idea is worth developing any further.

Main outcomes

The StartApp development has brought incubation of new business ideas from the local level – as known from the physical incubators located at universities – to the transnational level. This fits very well with the recent movements in society towards a global market. The StartApp represents a new way of integrating education, research, and innovation as it can easily be used in courses at the universities or business schools

Remaining challenges

One of the main challenges when operating an application like StartApp is to attract users and tutors. The collaboration with the real incubator I3P at Polito is essential for promoting the new virtual tool and for testing and developing it further.

4.2 Best practises for the design and use of E-link functionalities

In the design and implementation of on-line functionalities for entrepreneurs, we should strive for efficiency, effectiveness and relevance.

Efficiency:

- The platform should be easy to use, with short response time, and easy to navigate and interact.
- This goal is reached by the adoption of suitable open-source tools that are in active development and are highly optimized and customizable.
- With a metaphor: whenever possible, we don't reinvent the wheel, but we assemble and integrate existing wheels into a new vehicle concept.

Effectiveness:

- The platform should be able to deliver the needed information and/or interactive services.

- This means that curating the content is very important, ensuring that it covers the required topics and that is continuously updated. The best practices require devoting some personnel to editing and publishing the content, to avoid contents starvation.
- Also, the interactive tools (i.e., discussion forum, interactive Osterwalder canvas, ...) must allow a smooth handling of the interaction process between entrepreneurs and tutors.

Relevance:

- The provided tools should be considered useful and relevant by the intended target users.
- In Virtual Campus Hub a twofold approach was adopted: first identify functionalities, with a panel of experts (I3P tutors), then seek feedback from entrepreneurs during the trial phase.

5 Functionalities – collaboration environment

As part of project Virtual Campus Hub, a series of tools for online collaboration have been tested and also challenged on their capabilities to work across institutional and national borders. Other collaboration tools have already been tested in previous projects and are therefore only considered conceptually in Virtual Campus Hub.

5.1 MS SharePoint and the Virtual Campus Hub team site

The collaboration tool MS SharePoint is widely used at research and educational institutions e.g. for sharing of files, calendars and messages. It is also used by the partners of Virtual Campus Hub for sharing of documents, project planning, etc. At TU/e, it is a core part of the learning management system (LMS), providing teachers and students with state of the art functionality for document sharing and collaboration on (student) projects. The tool works across institutional and national borders but users normally receive a special ID through invitation from the host institution – in our case DTU. In connection with this project, MS SharePoint has been connected by TU/e to the Virtual Campus Hub infrastructure. The connection has allowed the partners to login to the project team site (after its migration from DTU to TU/e) with the user name and password of their local institution.

Main outcomes

The procedure of connecting MS SharePoint to SURFconext in the Netherlands is documented in a [guide by Surfnet](#) and it has been repeated step-by-step by TU/e in order to connect MS SharePoint to the Virtual Campus Hub using federated authentication. MS SharePoint is already widely used for cross-institutional collaboration and the impact of this new achievement is therefore expected to be large.

Remaining challenges

In Virtual Campus Hub the SharePoint site is used as a demo-environment. The next challenge in connection with this collaboration tool is to move to a real production environment.

5.2 Unified communications tool

An inventory of existing tools that are used for online communication at the Virtual Campus Hub partners has been made by TU/e early in the project. This work builds upon efforts in the previous project [Explore Energy Virtual Campus](#) (EEVC) where different tools for online communications were tested and best practises for using the tools for online meetings, virtual conferences, and poster sessions were listed. The reliability of the communications tools was limited and had a large impact on the quality of virtual events. This was usually not due to the tools themselves, but due to the fact that:

- *They were used across an institution's border:* the external users were often unfamiliar with the tool and needed to install it ad hoc for the online activity

- *There was limited technical support available or none at all:* Once technical problems occurred, they could not easily be solved, especially with the ad hoc users that didn't use the application on a regular basis.
- *It was not possible to connect tools to other tools for which the institution had invested in high quality end user equipment (camera's, microphones, managed bandwidth, etc.):* This means there regularly were problems with audio and video, due to inferior end user equipments, e.g. during remote lectures.

To overcome this problem, TU/e and SURFnet have tried to set up a pilot with a so-called unified communications hub (UC hub), which enables connecting different meeting tools and is also able, for example, to connect with traditional videoconference equipment, for which most institutions have a large installed base of high quality equipment. This allows participants in a meeting, lecture, or conference to participate with the tools at hand at their institution. The concept is very well aligned with the Virtual Campus Hub concept in that there is no need to adapt to a common standard, except for the general standard to connect to the hub, and that it aims to cross institutional and national borders.

Main outcomes

The close collaboration between TU/e and SURFnet in connection with Virtual Campus Hub had led to the idea of setup a pilot with a unified communications hub. A concept has been designed to realise this. The potential for unified communications hubs is very large because online collaboration and communication has become widely used at institutions all over the world and all experience the same problems when crossing their institution's borders.

Remaining challenges

The UC hub technology, which is needed to realise a unified communications tool, is still rather immature and less developed than federated login. Fewer standards are available and companies are not so eager to participate in experiment or to connect to the federated infrastructure yet.

5.3 Best practises for the design and use of collaboration environments

MS SharePoint

To realise a connection of MS SharePoint, institutions should follow the [guide by Surfnet](#). The tool can then be used for file sharing between institutions exactly as before. The difference is that users can login with the ID from their local university so they do not need to remember a separate user name and password for MS SharePoint. Previously, problems with the access have been the major barrier for using the environment actively for international collaboration activities.

Communication

Until unified communications hubs become more widely available, become better standardized and are able to connect to the federated login infrastructure, the best practices developed in EEVC for organizing online activities in education remain valid:

- Use scenarios
- Plan ahead
- Standardize setups
- Provide sufficient support
- Organize test sessions

6 Infrastructure

The technical infrastructure of Virtual Campus Hub has been designed by TU/e based on a survey of available technology at the partner institutions and detailed analyses of each partner's specific requirements. Frequent meetings between the partners and their national federations WAYF (Denmark), SWAMID (Sweden), IDEM (Italy), and SurfFederatie (Netherlands) have been held to identify the requirements for the Virtual Campus Hub environment and plan the inter-connection of the partners.

The objective of the Virtual Campus Hub infrastructure has been to create:

1. An inventory of the most important ICT barriers for international collaboration in education.
2. A demo platform to prove that some of these barriers can be removed:
 - Easy access to partners' applications
 - More efficient and more flexible setup of online activities or online participation in regular activities.
 - Easier collaboration with industry
3. A vision on how to apply these insights and experiences in concrete collaboration initiatives (e.g. international joint programs)

6.1 Architecture of the Virtual Campus Hub infrastructure

The infrastructure facilities are needed to “glue” all functionalities together, so they can be used in a cross-institutional and cross-border setting. For that purpose, the Géant infrastructure and some of its value-added services (VAS), which are still under development, are used. The Géant services which have been used are:

- *Federated authentication (cross border):* Access to partners' applications or those of external service providers (SP) through the user's account at his home institution. Realized by connecting partner institutions as IdPs and SPs to their national NREN federations, which in turn are connected through eduGAIN. A limitation at this moment is that industry is in principle not allowed to use the NREN infrastructure, even if many research and education activities are done in collaboration with industry. Some initiatives have been started to enable IdPs from industry to participate in such collaborations, but there is no general mechanism across NRENs yet to deal with this issue. Therefore in this project, members of industry have obtained guest accounts from the federations involved.
- *Group management:* A VAS that enables the creation of cross-institutional and cross-order groups, which information can be used for authorizing access of groups to applications (services). Think, for example, of a project site which only a certain group should be able to access. In this project the group

management module SURFteams from SURFconext (Surfnet) is used, as no general mechanism for group management across NREN federations is available yet. IdPs or SPs participating in a collaboration may provide local group information to SURFteams, which may combine or edit this group information at a global level (i.e. at the level of the virtual organization). Therefore, in this project, all SPs that make use of external group management are using SURFteams.

The architecture of the Virtual Campus Hub infrastructure is shown in Figure 6.

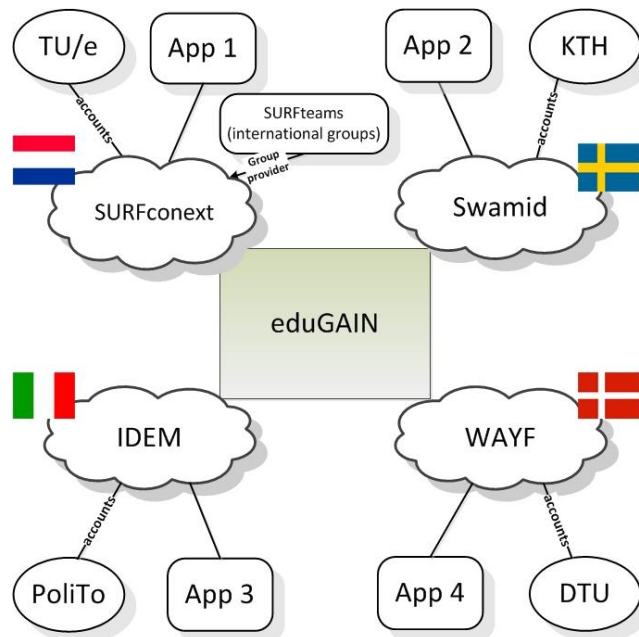


Figure 6. The architecture of the Virtual Campus Hub infrastructure.

Other Géant services which have been considered at the conceptual level but not used for the Virtual Campus Hub implementation include:

- *ID-mapping (also known as account-linking):* A VAS that is needed when access to applications or the retrieval of data from applications is related to a user's registration in a local administrative database. Think of the retrieval of a student's grades across different institutions (with the student having different ID's in each institution's administrative database or access to applications that are tightly integrated with an institution's administrative databases (e.g. the student and employee databases). In these cases, there needs to be a mechanism to relate a user's different IDs from different institutions to each other.
- *Exchange of presence and calendaring information:* A VAS that is needed to efficiently organize and setup online meetings, remote lectures and the like. This goes both for formally planned meetings and lectures and for ad hoc meetings. At present, setting up online meetings and lectures in cross-institutional and cross-border settings is time-consuming and cumbersome, as it is difficult for the organizer to obtain the information needed (availability, contact information,

contact for technical support, etc.). A standardized exchange mechanism for presence and calendaring info would help enormously.

- *Exchange mechanism for formal study program data:* A VAS needed to retrieve or edit program data from the different partners' administrative databases, e.g. course and scheduling information for joint programs, grades, etc. Next to a technical exchange mechanism, you also need to agree on a (set of) functional standard(s), e.g. IMS or RS3G. In case of publicly available data (such as course information), no authentication and authorization mechanism is needed. However, with sensitive or personalized data, the exchange mechanism must also provide for (federated) authentication and authorization (group management). In most cases, also ID-mapping will be needed in order to be able to find the relevant data in the different administrative databases.

6.2 Connections achieved in Virtual Campus Hub

The Virtual Campus Hub technology and achievements in connecting IdPs and SPs are described in the deliverable D5.4 Virtual Campus Hub technology evaluation report. In this section, a brief overview of the connection status by the end of the project is given.

IdPs connected

Three of the Virtual Campus Hub partners (DTU, KTH, and TUE) have been connected as IdPs via their local federations and eduGAIN. The Swedish (SWAMID) and Dutch (Surfnet) federations were already connected to eduGAIN when the project started. The Danish federation (WAYF) has connected to eduGAIN in order to fulfil requirements from Virtual Campus Hub.

The fourth partner, Polito, cannot be connected to the Virtual Campus Hub at present because the institution is not a member of the Italian federation IDEM. This decision has been taken by Polito's administration. Polito is focusing on Stork (eID) instead. In order to facilitate that Polito staff and external users can login to the Virtual Campus Hub environment, a number of guest IdPs have been connected. These include Feide OpenIdP, Onegini (for Social IDs), as well as SURFnet and GARR for testing.

SPs connected

DTU's courses in wind energy, which are hosted by the cloud service itslearning, have been connected. The connection has been realized via SURFconext in the Netherlands because itslearning in the Netherlands have got the technical expertise for this task whereas no expertise was found in Denmark. The possibility of connecting itslearning to WAYF is still being investigated and appears to be a complex task because WAYF uses different standards for federated authentication than Surfnet and SWAMID.

TU/e's collaboration environment MS SharePoint, incl. group management via SURFteams has been connected via Surfnet and eduGAIN.

Connection of KTH's remote labs has not yet been achieved despite a large effort by KTH staff and SWAMID. KTH is looking for external help on realizing the federated logon.

Polito's StartApp has not been connected as Polito cannot act as a SP as long as the institution is not connected to a federation.

6.3 Points of attention for using Géant/eduGAIN

Virtual Campus Hub has identified the main barriers for cross-institutional and cross-border collaboration. The project represents a pioneering effort in trying to overcome these barriers through connections to Géant/eduGAIN. This section summarises the learning points from Virtual Campus Hub when it comes to using the European E-infrastructure. The points of attention can be used as a guide for other institutions who wish to connect either as IdP or SP to Géant/eduGAIN. They can also be used as feedback to the NRENS, Géant and the Terena community so the process of connecting can be streamlined and simplified in the future.

Knowledge

- Institutions have little knowledge yet, which is a big barrier for using FIM/eduGAIN. Federations could be more active as knowledge brokers. Not necessarily by providing all knowledge themselves, but by having a network of partners (commercial and non-commercial) which they can draw upon to help institutions getting their applications or infrastructure connected. The same goes for the legal issues related to this.
- Federations could be more active in the beginning stages of a project to help institutions to work out the right architecture for an (inter)national collaboration or to serve as a knowledge broker in this (see above).
- Federations could be of great help to institutions with assessing the FIM/eduGAIN "readiness" of applications that an institution has or considers buying for the collaboration.
- Or: federations could serve as (technical and legal) brokers for cloud services (like would have been possible for itslearning in this project). This would not only enable institutions to buy "application + FIM" as a service, but would also enable federations to force
- People that decide on or initiate international collaborations mostly have no idea at all that something like federated logon exists and could be useful. More marketing efforts by federations could help a lot.
- For non-technicians, "federated logon" is not very spectacular. As a result, teachers and staff often feel that the workarounds they use (with guest accounts etc.) work well and using federated logon does not add much. This is also because most collaborations start small and FIM's added value is best felt when collaborations scale up. Once that happens, also the need for other functionalities besides federated logon is suddenly felt (e.g. group management, presence, calendaring, ID-mapping, exchange of formal data, etc.). Therefore, it would be good to show a possible growth path for the use of FIM and related functionality for (cross border) collaboration, so institutions and end users can get a feeling of what they can expect and better understand why FIM (usually starting with

federated logon) can be useful. So a general story on “what’s next and where will it lead us?” could be helpful, as well as an outline of the functionality needed for a collaboration and how they fit the bigger picture. Possibly also an outline of functionalities that federations are likely to provide and which ones are left to others.

Organisation

- For projects in this area, institutions need to involve federations and the relevant internal stakeholders from the start (i.e. when writing the proposal). In an international collaboration, there should be a clear division of labour between federations and local institutions. As in Virtual Campus Hub one partner (TU/e) has been coordinating the technical work of the partners involved (DTU, KTH, Polito), one federation could be coordinating the work of the federations involved (in this project SURFconext, SWAMID, WAYF, IDEM), as well as the work of eduGAIN. The coordinating partner and the coordinating federation should closely work together.
- As facilitating this kind of collaboration via Géant/eduGAIN is new, it is unclear which kinds of legal issues institutions/collaboration initiatives have to deal with and how to coordinate working out cross border legal issues. Federations are best placed to provide this kind of legal service or to serve as a knowledge broker in this (see above).

Homeless users

- There are few international collaborations that do not involve industry in some way or another. However, few federations allow industry to connect as IdP, which hampers the integration of research, education and innovation considerably.
- eID or social ID users are still “homeless” with respect to Géant/eduGAIN. Given that an increasing amount of “outsiders” need to obtain access to an institution’s facilities and given that this kind of outsiders often participate in an institution’s collaboration initiatives, login through eID should be made possible as well.
- Perhaps an organization such as eduGAIN could provide an IdP for the ‘homeless’.

Standardization

- At the start of the project, federated logon via federations/eduGAIN was, from the perspective of the institutions involved, expected to be a black box to which connections could be realized easily and without having to deal with the internal workings of this “black box”. This has been a disappointment, as this turned out to be anything but a black box yet. Federation architectures differ and there is often confusion on who has to do what to get connections working.
- Group management is a powerful functionality which can diminish the administrative burden for a collaboration initiative considerably once it is scaling up. The lack of standards across federations and eduGAIN and the limited availability of partners that can help implement group management for a service

(see above) is a serious barrier when considering facilitating international collaboration through federations/eduGAIN.

- There are different solutions available for creating guest accounts, which all more or less work the same (in this project FEIDE OpenIdP and SURFguest were used). A standard solution which could be used by all federations could be useful.

Technical

- Processing changes in metadata for eduGAIN seems to take a very long time, which slows the connection process considerably. For real collaboration initiatives, taking so much time for changes will be unacceptable.
- Institutions need to analyse the architecture needed to open up their internally focused ICT infrastructure to the outside world and take action. Their research and education activities have embraced the outside world a long time ago, but their ICT infrastructure is still stuck in the past with respect to external collaboration.

6.4 Where should we go from here?

This section contains some visions, based on findings in Virtual Campus Hub, for which direction the further development and exploitation of European E-infrastructure should go:

Towards institutions preparing properly for (cross border) FIM projects

- Involving all relevant stakeholders (both federations and internal stakeholders) from the start, i.e. when writing the proposal
- Analyse the architecture needed to open up the internally focused ICT infrastructure to the outside world (as R&E processes using it have done a long time ago)

Towards institutions knowing about (cross border) FIM

- People who decide on or initiate (international) collaborations mostly have no idea at all that something like federated logon and more exists and could be useful. More marketing efforts by federations might help.

Towards institutions wanting (cross border) FIM

- (cross border) FIM as a growth path: what's next and where will it lead us
- Beyond "federated logon only": group management, ID-mapping, presence, calendaring,...? Which functionalities are needed and how do they fit the bigger picture? What are federations likely to pick up and what is left to others?

Towards (cross border) FIM as a utility service

- Black box for institutions
- Standardization / attuning technology involved in inter-federation (e.g. group management)

- A general solution for guest accounts would be welcome (perhaps via eduGAIN)?
- Coordination of (inter)federation work by federations themselves
- Federations as (technical and legal) brokers for (cross border) cloud services?

Towards federations as knowledge brokers for institutions

- Institutions have little knowledge; they need to know who to ask (about technical and legal issues)
- Federations could assist institutions in working out the right architecture for (international) collaborations
- Federations could assist institutions in assessing the “FIM readiness” of applications that an institution has or considers buying

Towards federations accepting reality

- R&E collaboration with industry and others is there to stay. Treat it as such.
- Thus: acceptance of industry IdPs, eID, social ID and perhaps other solutions?

7 Presentation in portal

Using services from different partners in a (cross border) virtual organization or from external service providers that service this virtual organization sets extra requirements to the presentation layer (portal) compared to an institution’s internal portal. These extra requirements are:

- *Usability:* The services from all partners and external SPs must be presented as a coherent whole to the end user.
- *Reuse:* Partners are often involved in different partnerships, so components must also be reused in other partnership portals or be embedded in the own home portal.

For these reasons (usability and reuse), the Virtual Campus Hub concept includes:

- A demo portal based on a general standard at one of the partners (TU/e). The idea is that partners could setup a similar portal and be using the same services.
- Present services through gadgets or portlets in order to:
 - a. Present the services from different service providers (partners, external) as a coherent whole to the end user.
 - b. Enable their reuse in other portals. For example, other portals could use a different set of services, incl. some of the Virtual Campus Hub demo services.

A demo-portal has been developed by TU/e as part of Virtual Campus Hub. The portal is found at <https://vch.tue.nl/> and Figure 7 shows the access page.

Users of the different Virtual Campus Hub applications can access via the portal or directly through the interface for each application. For connected IdPs, the login is performed with the user name and password of the local institutions. Other users can access via a guest account.

The Virtual Campus Hub portal can be used to divide users into groups (e.g. students who follow an educational programme). The groups can be managed centrally from here and synchronized into other Virtual Campus Hub applications. The centralised group management has been demonstrated for the MS SharePoint site at TU/e.

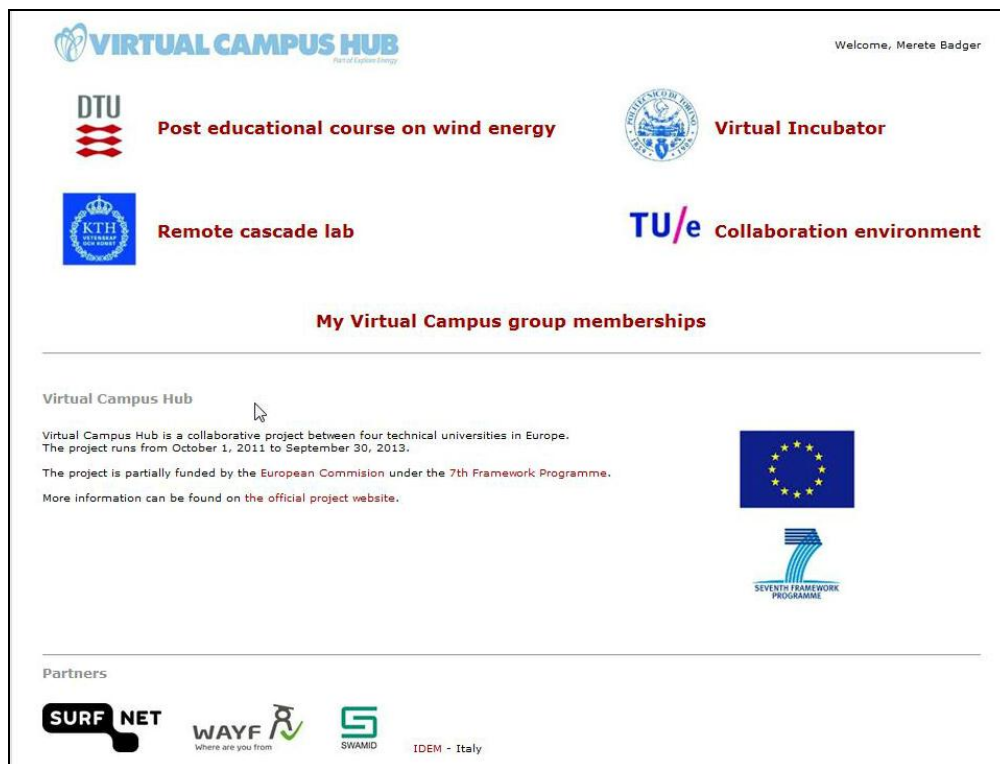


Figure 7. Screen shot showing the Virtual Campus Hub Portal.

8 Impact

Virtual Campus Hub has led to significant advances in the use of European research infrastructures across institutional and national borders and the Virtual Campus Hub demo platform has already inspired other consortia to get connected in a similar way (e.g. the [Eurotech](#) partners: DTU, TU/e, TUM Munich, EPFL Lausanne). The user requirements and the remaining barriers for fulfilling these have been identified through the project and communicated back to the NRENS and to other E-infrastructure bodies at the international level (Géant, the Terena community) throughout the project.

Virtual Campus Hub has boosted the use of state-of-the-art E-learning tools and sharing of resources at the partner universities. The good examples of E-learning in Virtual Campus Hub have already sparked an interest for developing new E-learning applications and the use of such applications is beginning to penetrate into university programs and courses as a result of dissemination activities in Virtual Campus Hub.

Virtual Campus Hub has identified new ways of achieving a further integration of research, education, and innovation. For example, participants in the WASP E-learning course were a mixture of university students and staff and people from the wind energy industry. This was an excellent networking experience for all. The StartApp is another example of the integration of businesses in the university world.

In the following, some key facts and figures related to Virtual Campus Hub's impact are listed. More details can be found in the deliverable D6.6 Strategy paper.

Key facts and figures from Virtual Campus Hub

- 300 university students have used an E-learning application from Virtual Campus Hub as part of their programme (some students have used several applications and the total number of times the Virtual Campus Hub applications have been used is therefore around 1,000).
- 25 university teachers have been involved in online teaching and/or development of online teaching material in Virtual Campus Hub.
- 6 types of online applications have been developed: remote labs (3), examination tools (2), online courses (3), the StartApp for entrepreneurs (1), a collaboration environment (1), and a unified communications environment (1).
- 9 Virtual events have been carried out where applications of Virtual Campus Hub were tested in real teaching situations.
- 37 users have registered at the Virtual Campus Hub Portal.
- 4 European nations, 4 NRENS, and 4 technical universities have exchanged requirements and experiences through Virtual Campus Hub.

- 3 core disciplines have been integrated in Virtual Campus Hub: education, research, innovation.
- 3 levels of renewable energy education have been engaged in Virtual Campus Hub: Master, Ph.D., continuous education (life-long-learning).

9 Business models in Virtual Campus Hub

The different applications, which the partners of Virtual Campus Hub have chosen to develop or share, remain the property of the partners. It is therefore up to each partner to develop a business model for their applications and secure their sustainability. Some applications will remain open access and others will be available as part of university programs and courses in sustainable energy. The business model and the sustainability plan for each application are described in more detail in the deliverable D6.6 Strategy paper.

For the Virtual Campus Hub concept as a whole, different business model scenarios have been discussed. A final decision regarding the future of the Virtual Campus Hub concept has not yet been taken. Different scenarios for the future are:

- Once the Virtual Campus Hub concept has been described in detail through the project deliverables and the demo portal, it is openly available to other users who wish to collaborate with each other (e.g. universities in joint educational programs). It is then up to the users, together with their local federations and service providers, to set up and operate a system similar to Virtual Campus hub.
- The project team of Virtual Campus Hub and the federations involved in the project continue to offer their services via the Virtual Campus Hub infrastructure and help new users to connect for a fee (up-scaling). The up-scaling is not limited to educational purposes, as the Virtual Campus Hub concept could just as well be used by research projects and, possibly, innovation (requires easier access for industry partners). Federations and eduGAIN are now widely implemented around the world so the collaboration could be extended to the global scale.
- The project team looks for a start-up company (SME) who is willing to run and develop the Virtual Campus Hub concept further. KIC InnoEnergy would be the perfect access point for realizing such as public-private partnership. The project team is in dialogue with KIC InnoEnergy about the possibilities.
- The European Commission has already expressed some interest in supporting the sustainability of Virtual Campus Hub via European infrastructure resources – a dialogue with DANTE could be initiated to find out more about possibilities for realizing this scenario.

10 Other initiatives supporting the vision of Virtual Campus Hub

Project Virtual Campus Hub has identified a possible structure for a new “open learning” environment which supports sharing of learning content and other resources that make collaboration between institutions easier. Other initiatives have emerged in parallel with Virtual Campus Hub, which also support sharing of resources for learning and collaboration. In the following, some of these initiatives and their synergies with Virtual Campus Hub are described.

10.1 Related projects

The partners of Virtual Campus Hub have previously worked together in the project [Explore Energy Virtual Campus](#) (EEVC, 2010-12). In EEVC, the partners worked towards a vision of establishing a virtual campus with all of the formal and informal elements known from a physical university campus (e.g. lectures and conferences, poster sessions, virtual incubator facilities, and a coffee house).

A range of applications, which mostly focused on synchronous learning and collaboration, were developed in EEVC to demonstrate the virtual campus idea. A major barrier for using the synchronous applications turned out to be that the technology would often fail to support the planned activities. In Virtual Campus Hub and other recent initiatives, this problem has been addressed through a switch towards asynchronous learning and collaboration. Some of the applications from EEVC (e.g. the virtual conference room and coffee house) could be implemented in the Virtual Campus Hub as illustrated in Figure 8.

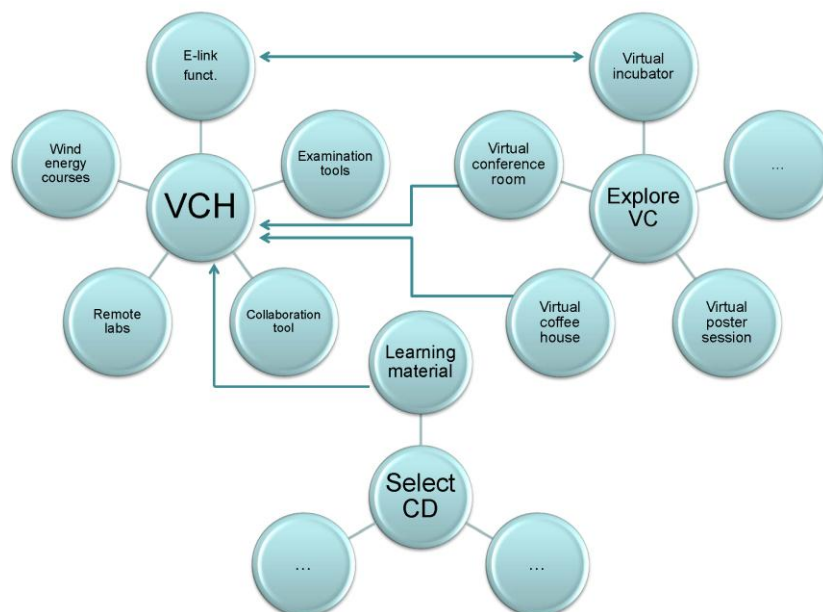


Figure 8. Diagram showing possible synergies between project Virtual Campus Hub and the previous projects Explore Energy Virtual Campus and Select CD.

Three partners of Virtual Campus Hub have been involved in the project [Select CD](#) (2010-12) about curriculum development in support of the Erasmus Select M.Sc. programme in sustainable energy. The learning material has been distributed via the international learning platform CompEdu and could potentially also be linked to the Virtual Campus Hub. The EEVC, Select CD, and Virtual Campus Hub projects can be seen as stepping stones towards a common vision of opening and sharing resources for education in the field of sustainable energy. The three projects and several others can be found through the [Explore Energy gateway](#) hosted at KTH. This gateway represents a first attempt to setup a common access point for education, research, and innovation activities related to sustainable energy.

10.2 Massive Open Online Courses (MOOC)

In parallel with Virtual Campus Hub, another mind set for online learning – the Massive Open Online Courses (MOOC) has evolved. A major step forward was taken in the spring of 2012 when the open platform [Coursera](#) was launched as a partnership between some of the major universities in the US. Coursera has expanded rapidly and today there are 62 partner universities – DTU is one of them. All Coursera courses are offered at no cost and attract thousands of students from around the world. The completion rate is typically around 10% of the course participants.

The E-learning applications developed in Virtual Campus Hub are designed to be integrated in university programs and courses. Here the long-term goal is a completion rate close to 100% of the participating students as well as accreditation of ETCS credits. The tests in Virtual Campus Hub have proved that such a high completion rate can be achieved through intensive supervision of the students and follow-up on their learning progress. Such activities are labour-intensive and it is therefore necessary to charge a fee for the E-learning applications, or to offer them as part of university programs and courses which already generate an income to the university. The strategy at DTU is to develop a few flagship courses, which can be offered at Coursera and promote the university. However, for most of the existing and future E-learning tools, sharing is likely to be restricted to DTU's partners in different programs and alliances.

A very important difference between the E-learning applications of Virtual Campus Hub and the MOOCs is that Virtual Campus Hub facilitates the use of in-house tools and standards. The Virtual Campus Hub concept is about sharing and unlocking these resources without adapting them to a common format. MOOCs, in contrast, are hosted on a common platform using a set of common standards, which new applications have to be adapted to.

10.3 Gamification

Another recent movement in the E-learning area is called gamification, which means that elements known from the gaming industry is used for other purposes – in this context for education. Examples of gamification could be that students earn points each time they complete a learning module, an exercise, or a test. Competition amongst the students might be a motivating factor, which can be used constructively

in the learning process. The WAsP E-learning course has a point system but no competition elements are included. In contrast, students are encouraged to help and support each other in the learning process. This approach works well in connection with continuous education but for a younger target group it might be a good idea to introduce competition.

In life sciences, a portal for laboratory exercises called [Labster](#) is available. It is owned by a commercial company and has a very different business model from the MOOCs. Access to the lab exercises is granted through payment of a fee and the lab experiments are mostly based on advanced computer simulations. This means there is no limitation to the number of students who can follow simultaneously in contrast to the remote lab exercises of Virtual Campus Hub where real equipment is used. The Labster simulations are built as a gaming environment and have a very high visual quality. The portal could be used as inspiration for further developments of an access point for energy related content of many different kinds. In order to run such an enterprise, universities would benefit from collaboration with one or more SMEs.

11 Conclusions and outlook

11.1 Achievements in Virtual Campus Hub

In the framework of Virtual Campus Hub, the partners have delivered a series of applications for online teaching and collaboration and demonstrated the use of these tools in real teaching situations. Based on thorough testing, recommendations of *best practises* for the development and use of each Virtual Campus Hub application have been given. The Virtual Campus Hub partners and some of their applications have been connected to the Virtual Campus Hub environment – a *technical platform* which facilitates single-sign on and central management of users and groups.

The technology behind the Virtual Campus Hub environment is the European research infrastructure Géant/eduGAIN combined with NRENS. Virtual Campus Hub has demonstrated for the first time how eduGAIN can be used to connect universities, and some of the services they wish to offer, across national borders. The project has also shown that some barriers remain for making connections easy and achievable for any educational institution or external service provider. For example, institutions or individuals from the private sector must be included in the existing research infrastructure in order to support a further integration of research, education, and innovation.

Virtual Campus Hub has led to significant advances in many different areas including ITC, international collaboration, E-learning tools and pedagogy, and integration of education, research, and innovation in the field of sustainable energy. The new knowledge gained from Virtual Campus Hub has been *disseminated* via a number of different channels. These include participation in scientific and educational conferences, publication of conference papers and reports, communications on the [project web site](#) and on social media ([Facebook](#) and [Twitter](#)), and participation in a series of strategic meetings and workshops about online education and collaboration in the future.

A large number of teachers and students at the partners have been involved in the development and testing of Virtual Campus Hub applications and an *inventory of staff competences* has thus been built up throughout the project period. Another important achievement of Virtual Campus Hub is that teachers who have been involved in the project are starting to see the benefits of opening up and sharing learning content with an international learning community. Other teachers have expressed an interest in developing new online learning material based on the recommended best practises from Virtual Campus Hub. In this way, up-scaling of the concept has already started.

11.2 Outlook for the future

Virtual Campus Hub's applications are designed to be sustainable beyond the project period and each partner is responsible for developing a sustainable business plan for its own applications. The Virtual Campus Hub portal will be kept open for a period of three months after the end of the project. A new strategy has to be made for the

sustainability of the portal after that. In any case, the documentation of the Virtual Campus Hub concept, technology, applications and best practises ensures that the concept can be re-used by others who wish to setup a similar environment in the future.

The Virtual Campus Hub concept has been demonstrated through a pilot environment which connects the partners and their services. A natural next step would be to implement the concept in connection with real learning and collaboration environments e.g. in support of a joint educational program in energy. The Virtual Campus Hub consortium is currently in dialogue with the Eurotech universities about the possibilities for future collaboration. The consortium has also approached the strategic energy alliances [SEEIT](#) and [KIC InnoEnergy](#).

Another way of advancing the Virtual Campus Hub concept in the future would be to develop a procedure for further up-scaling. The up-scaling could potentially embrace many types of new users from various disciplines and educational levels (elementary schools, vocational training, universities, and continuous education). A geographical expansion of the Virtual Campus Hub concept towards the global scale is also a natural next step to take as more and more countries have federations and connections to eduGAIN.

In preparation for the Horizon 2020 calls for proposals, the partners of Virtual Campus Hub will prepare a roadmap for the further requirements of a working Virtual Campus Hub environment that links to Virtual Campus Hub's vision of sharing resources for education at the European and the global scale. The roadmap will also be linked to overall strategies for energy education (the SET-plan) and for E-infrastructure in Europe.

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Appendix: Deliverables of project Virtual Campus Hub

This appendix shows the project deliverables of Virtual Campus Hub. The red links can be used to access the publicly available (PU) deliverables via the project web site.

List of project deliverables:

Management of the Consortium

[D1.1 Mid-term report \(PU\)](#)

[D1.2 Final report \(PU\)](#)

E-learning Tools

D2.1 Interim report on pedagogical improvement

[D2.2 Implementation of e-Learning tools \(PU\)](#)

[D2.3 Report on pedagogical improvement \(PU\)](#)

E-learning Programs and Courses

D3.1 Prototype implementation of e-Learning tools and incubator processes

[D3.2 Trial implementation and test of two e-Learning tools \(PU\)](#)

[D3.3 Trial implementation of two incubator processes \(PU\)](#)

[D3.4 e-Learning programs and courses evaluation report \(PU\)](#)

E-link Innovation for Decision Makers

D4.1 Interim e-Link evaluation report

[D4.2 e-Link functionality integrated into the VC hub \(PU\)](#)

[D4.3 e-Link evaluation report \(PU\)](#)

Virtual Campus Hub Technology

D5.1 Preliminary technology survey report

D5.2 Technical concept and recommendations for the specifications of the VCH inventory and demonstrator

[D5.3 Virtual Campus Hub technology \(PU\)](#)

[D5.4 Virtual Campus Hub technology evaluation report \(PU\)](#)

Dissemination and exploitation

[D6.1 Dissemination strategy paper - preliminary version \(PU\)](#)

[D6.2 Virtual Campus Hub website \(PU\)](#)

D6.3 Virtual Campus Hub workshops and meetings

[D6.4 Virtual Campus Hub virtual events \(PU\)](#)

[D6.5 Virtual Campus Hub conference \(PU\)](#)

[D6.6 Strategy paper \(PU\)](#)

[D6.7 Final report on the Virtual Campus Hub concept \(PU\)](#)

DTU Wind Energy
Technical University of Denmark

Frederiksborgvej 399
4000 Roskilde
Denmark
Phone +45 4677 5024

www.vindenergi.dtu.dk